National Aeronautics and Space Administration

Airborne Hyperspectral Imaging Studies of Harmful Algal Blooms

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Importance of Monitoring Great Lakes Harmful Algal Blooms (HABs)

- In the Great Lakes an example is a Microcystis bloom which has reoccurred in western Lake Erie, Saginaw Bay, and Lake Ontario since at least 1995
- Cause for return of algal bloom is still being investigated – key drivers are water temperature and nutrient loading
- Microcystis may contain a toxin, Microcystin, which can be harmful to humans, fish, and wildlife
- Multiple recent blooms have occurred since 1995 where the Microcystis concentration was significantly higher than the World Health Organization recommendations for drinking water
- Goal is to develop remote sensing capability to detect the pigment Phycocyanin, an indicator of Microcystis, in low concentration as an early indicator of bloom prediction

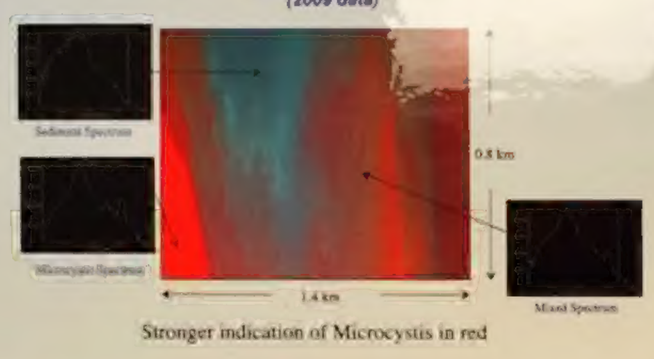
Brief History of NASA GRC Hyperspectral Imaging in Collaboration with NOAA, UT, KSU, MTRI, Ohioview, and OAI

2006—Developed Generation I miniature Hyperspectral Imager (HSI). Weighed less than 4 kg and about 11 x 16 x 3 cm in size
2006—Acquired HSI data of Algal blooms in Lake Erie and Grand River sediment plume in Lake Michigan with concurrent water sampling conducted by NOAA GLERL and others
2007—Developed 2nd generation HSI that is about twice the size of the Gen I instrument. Specifically designed for remote sensing water quality application (low reflectivity ~6% max)
2007—Acquired HSI data of Algal blooms in Lake Erie and Saginaw Bay with concurrent water sampling conducted by NOAA GLERL and others
2009—Acquired concurrent water samples and over-flight of 75 data points
2013—Initiated Great Lakes Workshops and plans for further collaboration
2014—Conducted collaborative HICO/airborne hyperspectral/ground campaign partly in response to Ohio state of emergency due to harmful algal bloom

Hyperspectral Imaging Data

Produce Microcystis Indication Map

(2009 data)



Stronger indication of Microcystis in red

Comparison of MODIS Image From Terra Satellite With Airborne Hyperspectral Image (inset)

(both taken on Sept. 5, 2006)

How Aerial Monitoring Fits With Other Measurement Capabilities

- *In Situ* – many physical measurements at a point but poor spatial coverage
- *Satellite* – Measurements over a large area but poor / marginal temporal coverage
- *Aerial* – Monitoring is Complementary
  - More frequent measurement opportunities to understand rapidly changing blooms
  - Lower concentrations potentially detectable because of higher spatial and spectral resolution
  - Can quickly locate areas of interest and guide in situ measurements
  - Easily tailor instrumentation to suit the problem

Observation Method	Observation Frequency	Resolution
Satellite Landsat TM	Once every 8 days	30 meter
Satellite MODIS	2/day	1km
Satellite MERIS	Every 2-3 days	250m
Satellite SeaWiFS	1/day	1km
Research Vessel In situ	Flexible	Point
Aerial Monitoring	As Needed	1- 5 m (Variable)

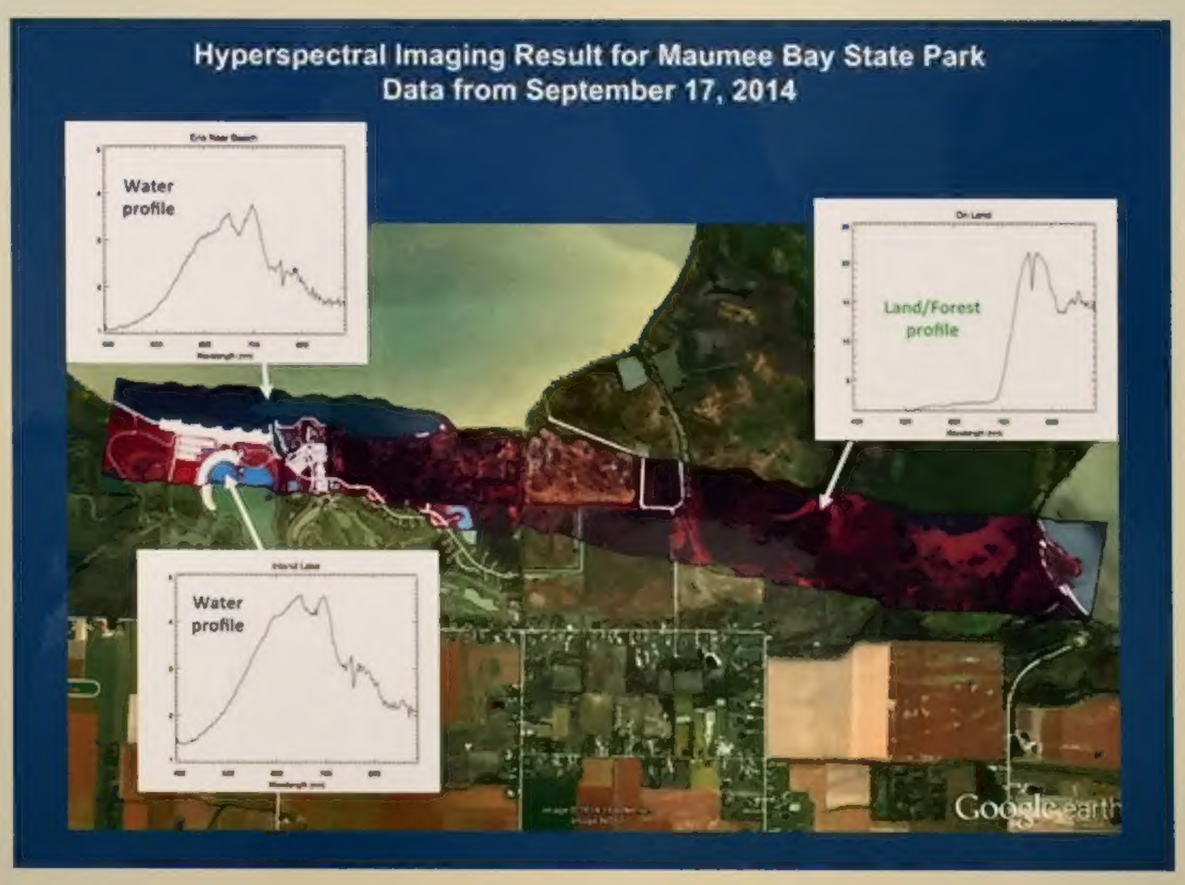
Spatial Variability in PC* concentration

**PC = Phycocyanin, a pigment & indicator of microcystis*

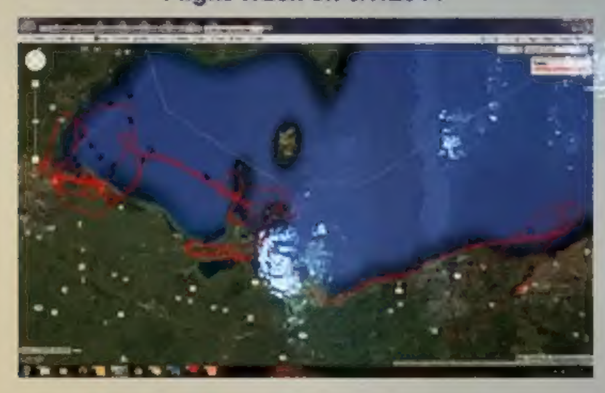
- Note that there are ribbons of very high concentration within 100 meters of sample location
- Repeat water samples from this location varied by 36%
- Both HSI data and repeat sample variability suggest that the sample point is in an area with strong concentration gradient

- Sample location is shown by pushpin
- Higher indication of microcystis is indicated by red coloring

Hyperspectral Imaging Result for Maumee Bay State Park
Data from September 17, 2014

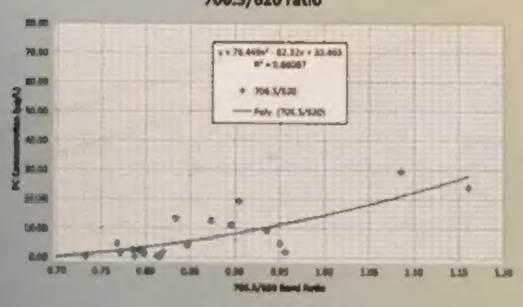


Flight Track on 8/7/2014



Band Ratio Correlation to PC Concentration

706.5/620 ratio

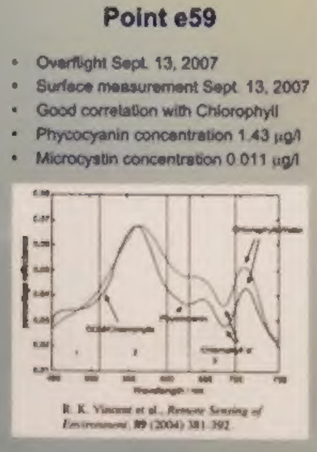


Simis, et al. (2005)

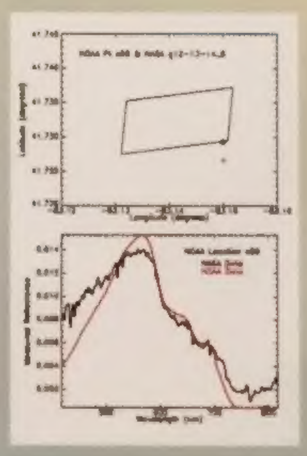
Aerial Campaign Photo – 8/15/2014
Lat 41 42.710 N Lon 83 15.102 W

Point e59

- Overflight Sept. 13, 2007
- Surface measurement Sept. 13, 2007
- Good correlation with Chlorophyll
- Phycocyanin concentration 1.43 µg/l
- Microcystin concentration 0.011 µg/l



R. K. Vincent et al., *Remote Sensing of Environment* 89 (2004) 381-392

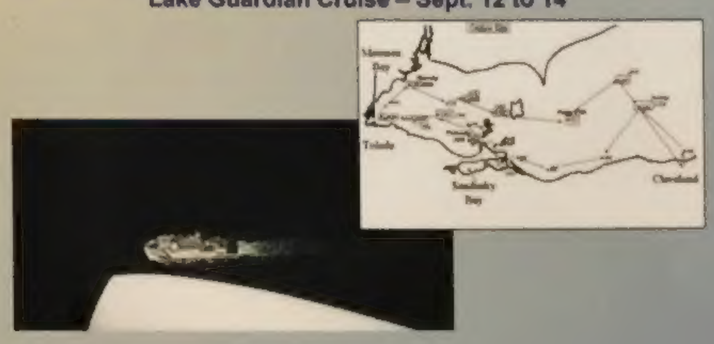


Simultaneous Water Surface Measurements

Maumee Bay State Park *(8/5/2014)*

Dr. Ricky Becker, University of Toledo (Left). Dr. Joe Ortiz, Kent State University (Right)

HSI Data Acquisition Occurred at the Same Time as the EPA R/V Lake Guardian Cruise – Sept. 12 to 14



Summary of Harmful Algae Bloom (HAB) Research

- Two generations of HSIs have been built and flight tested in recent years
- Data has been acquired in 2006, 2007, and 2009 with concurrent water sampling
- Concurrent surface reflectance from 2006 and 2007 measurements match well with airborne reflectance measurements
- 2009 results show that a band ratio technique typically used for remote measurement of Chl-a had best correlation to Phycocyanin concentration
- 2014 focusing on expanding partner ground truthing and utilizing updated measurement protocols

Future of NASA GRC Hyperspectral Research

- Continue to conduct flights and refine algorithms
- Apply airborne hyperspectral on various platforms for various purposes
  - Water quality and hydrology
  - Ecosystem
  - Mining
- Contribute to science of imaging spectrometry
  - Airborne campaign for satellite missions
  - Expanding partnership for ground truthing and protocols, calibration, atmospheric correction, and utilization of hyperspectral remote sensing
  - Exchange of results